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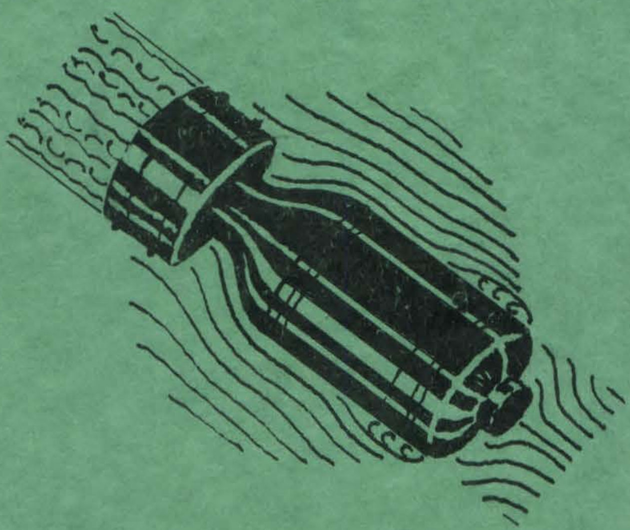
WATER TUNNEL TESTS OF THE MK 13 TORPEDO WITH SPADE AND STABILIZER RING NOSES



THE HIGH SPEED WATER TUNNEL

CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA.

SECTION Nº 6.1 - Sr - 207-1278

ND - 15.2

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WATER TUNNEL TESTS

OF THE

MK 13 TORPEDO

WITH

SPADE AND STABILIZER RING NOSES

BY

ROBERT T. KNAPP
OFFICIAL INVESTIGATOR

THE HIGH SPEED WATER TUNNEL
AT THE
CALIFORNIA INSTITUTE OF TECHNOLOGY
HYDRAULIC MACHINERY LABORATORY
PASADENA, CALIFORNIA

Section No. 6.1-sr207-1278

HML Report No. ND-15.2

Report Prepared by
Harold L. Doolittle
Hydraulic Engineer

May 30, 1944

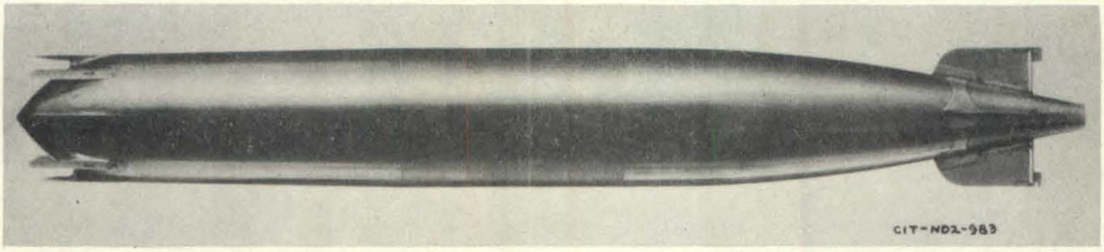

FIGURE 1

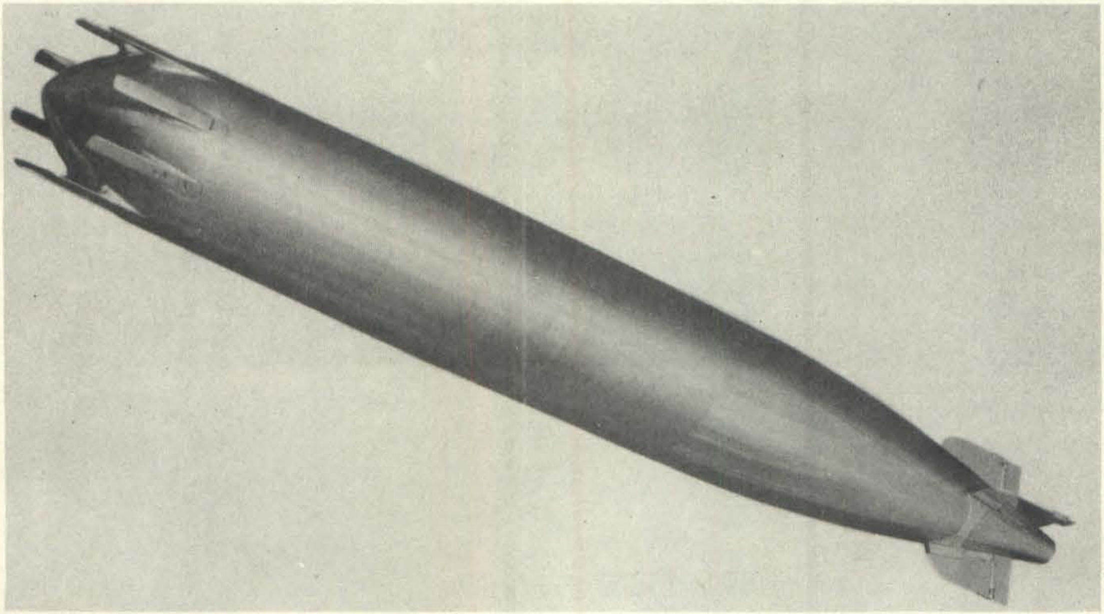

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FIGURE 2

PHOTOGRAPHS OF MODEL WITH NO. 90 NOSE
0.92 CALIBER OGIVE WITH 8 SPADES

WATER TUNNEL TESTS

OF THE

MK 13 TORPEDO

WITH

SPADE AND STABILIZER RING NOSES

GENERAL

This report covers tests of a 2" diameter model of the MK 13-1, 13-2, and 13-2a torpedoes conducted at the Hydraulic Machinery Laboratory of the California Institute of Technology. The model was made up of a MK 13-1, 13-2, and 13-2a afterbody with special noses. These noses were connected to the afterbody by a cylindrical section instead of the slightly tapered section used on the prototypes. As the MK 13-1, 13-2, and 13-2a torpedoes are identical in dimensions and shape and differ only in the weight of the charge carried (see Report Section No. 6.1-sr-207-936), the MK 13-1 torpedo only will be referred to hereafter. This work was carried out under Project NO 141.

The object of these tests was to determine the drag coefficients and cavitation behavior of noses fitted with spades and stabilizing rings that have been designed to improve the entrance characteristics of the torpedo. All tests were made with neutral rudder settings and at zero yaw angle.

The model was mounted in the High Speed Water Tunnel and photographs were taken to show the performance at several degrees of cavitation. The drag was also measured for several water velocities.

DESCRIPTION OF TORPEDO SHAPES TESTED

These tests were made on three different types of noses having laboratory designations, Nos. 90, 91, and 92.

Figures 1 and 2 show the No. 90 nose, which is a 0.92 caliber ogive fitted with eight spades. The No. 91 nose is shown in Figures 3 and 4. This is a hemisphere to which has been added a stabilizing ring 0.493 caliber in diameter having four points of contact with the nose. The No. 92 nose, shown in Figures 5 and 6, has the same stabilizing ring as the No. 91 nose but the nose proper is a 2 x 0.35 caliber spherogive, i.e., a 2 caliber ogive rounded off with a sphere of 0.35 caliber diameter. Figure 7 gives the general dimensions of the spades and stabilizing ring.

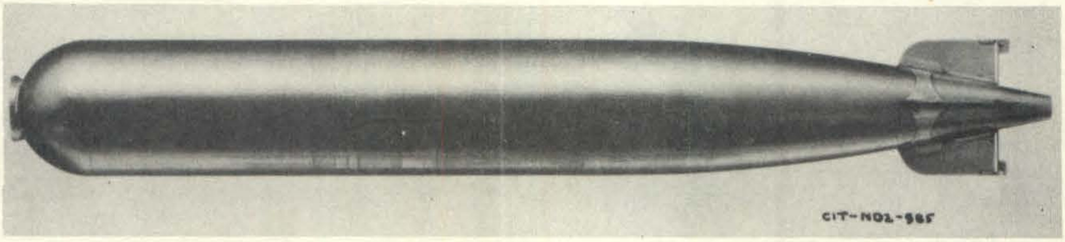

FIGURE 3

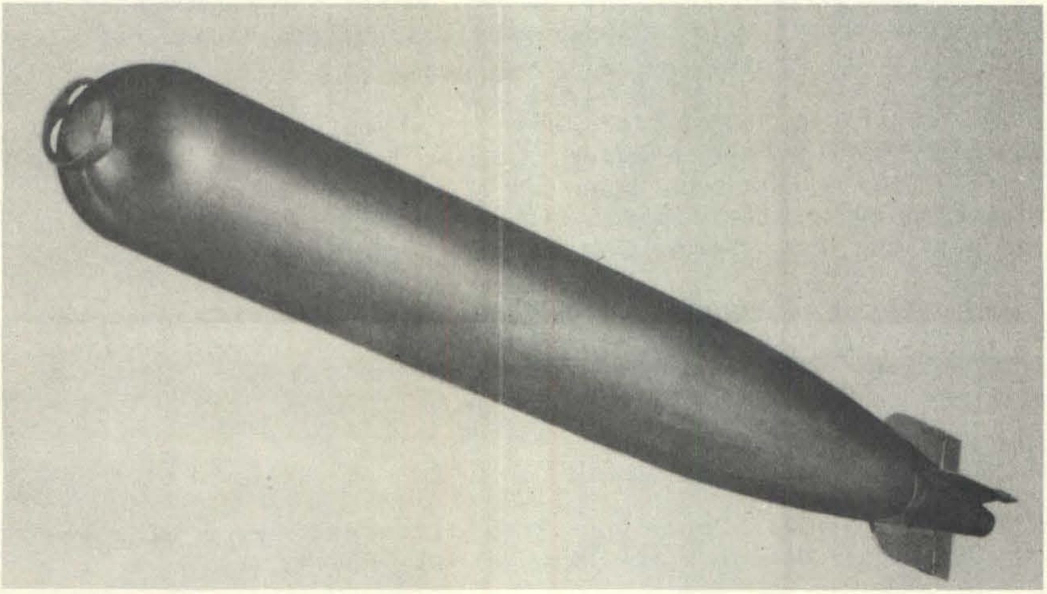

FIGURE 4

PHOTOGRAPH OF MODEL WITH NO. 91 NOSE
HEMISPHERE WITH STABILIZING RING

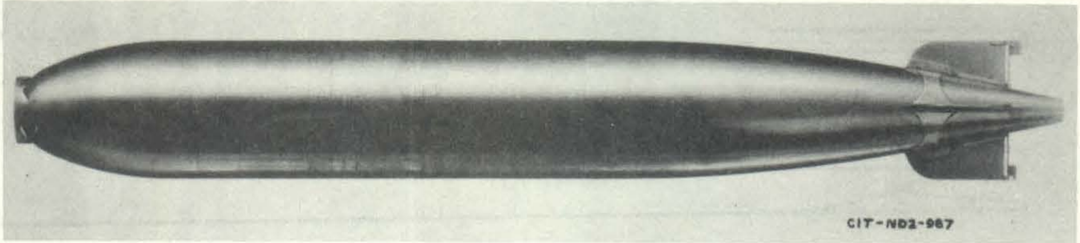

FIGURE 5

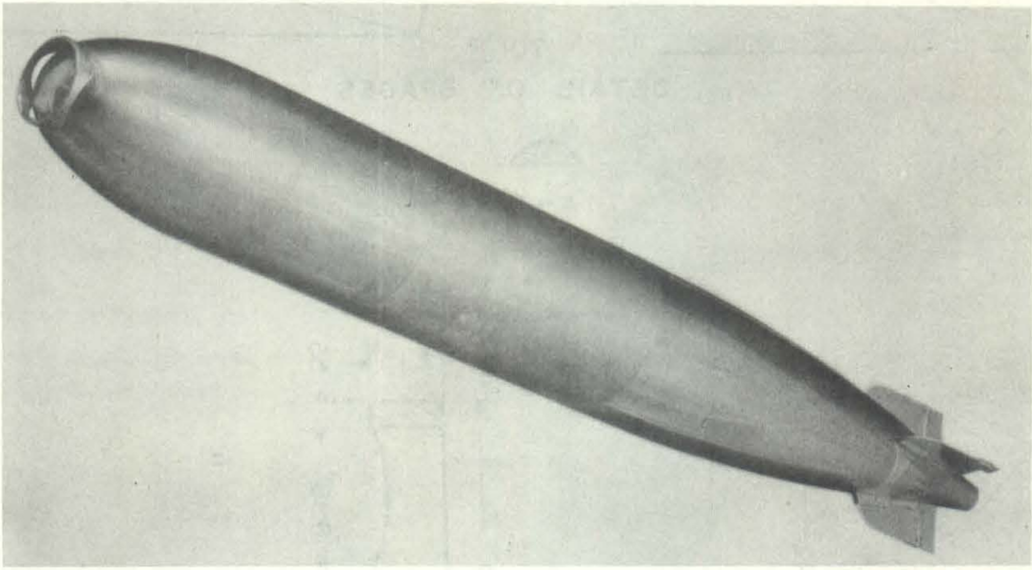

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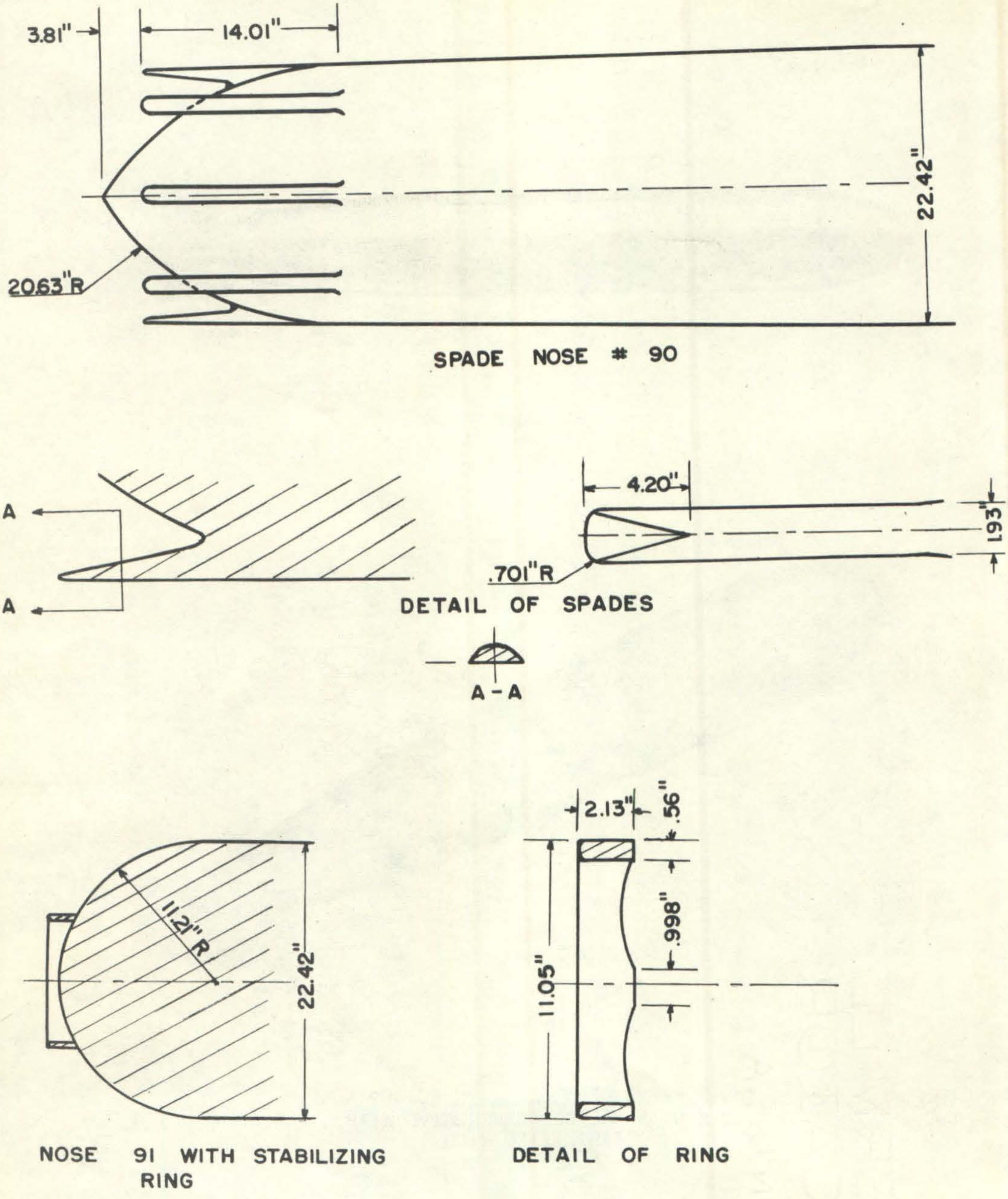
FIGURE 6

PHOTOGRAPHS OF MODEL WITH NO. 92 NOSE
2 x 0.35 CALIBER SPHEROGIVE WITH
STABILIZING RING



DETAILS OF NOSES # 90 AND # 91

FIGURE 7

DRAG MEASUREMENTS

Runs were made with the three noses and the drag measured at three different velocities. In Table I are given the drag coefficients calculated from these data, all being corrected for interference of the support shield.

TABLE I

NOSE NO.	DESCRIPTION	VELOCITY f p s	DRAG COEFFICIENT C_D
90	8 spades on 0.92 caliber ogive	20.0	0.182
		25.3	0.183
		30.1	0.183
91	Stabilizer ring on hemisphere	20.0	0.163
		25.3	0.142
		30.1	0.154
92	Stabilizer ring on 2 x 0.35 caliber spherogive	20.0	0.168
		25.3	0.161
		30.1	0.162

Table II shows the drag coefficients for the three modified noses in comparison with the drag for the MK 13-1 torpedo with the standard nose. These values were obtained by extrapolating the model data to the prototype speed of 33.5 knots and the resulting reduction in speed for the three noses has been calculated.

TABLE II

COMPARISON OF NOSES FOR THE MK 13-1 TORPEDO

NOSE	MODEL AT 30 FPS.		EXTRAPOLATION TO PROTOTYPE AT 33.5 KNOTS		PROTOTYPE VELOCITY	
	C_D	% OF MK 13-1 TORPEDO	C_D	% OF MK 13-1 TORPEDO	KNOTS	% OF MK 13-1 TORPEDO
Standard MK 13-1	0.140	100	0.071*	100	33.5	100
8 spades on 0.92 caliber ogive	0.183	131	0.114	161	26.5**	79
Stabilizer ring on hemisphere	0.154	110	0.085	120	30.5	91
Stabilizer ring on 2 x 0.35 caliber spherogive	0.162	116	0.093	131	29.2	87

* See Note A Page 6

** See Note B Page 6

The appreciable increase in drag and decrease in velocity due to the rings and spades makes it impracticable for these devices to remain on the torpedo during the run.

It should be noted that all of these drag measurements and calculations are for pressures and submergences at which no cavitation exists. For cavitating conditions the drags would be considerably higher and the speeds correspondingly lower.

Note A

The value of 0.071 for the drag coefficient for the standard MK 13-1 torpedo at a speed of 33.5 knots was obtained from a previous report (1) where it was calculated by extrapolating model data. The reduction in C_D between the model and prototype is 0.140 - 0.071 = 0.069 and is due to the so-called Reynolds number or scale effect. Nearly all of this reduction is due to the decrease in skin friction, since the part of the drag coefficient due to the form or shape of the body is relatively insensitive either to the size of the body or the velocity of flow. Since the differences in area of the various noses involved are negligible in comparison to the total surface area of the torpedo, it is reasonable to assume that the scale effect will be the same for all the combinations tested. Therefore, the drag coefficients for prototype speeds may be calculated by subtracting 0.069 from the drag coefficients for the model. The values of C_D in the third column of Table II have been calculated in this manner. By comparing the relative values of the coefficients for model and prototype in Columns 2 and 4, respectively, it is seen that the relative increase in drag for the prototype exceeds that indicated by the model results.

Note B

To calculate the velocity of the torpedo with the various noses, use is made of the relationship that the propeller thrust (T) is equal to the drag (D) and that they remain constant in all cases. We can, therefore, write:

$$T = D = C_{D_1} A \rho \frac{V_1^2}{2} = C_{D_2} A \rho \frac{V_2^2}{2}$$

or

$$V_2 = V_1 \sqrt{\frac{C_{D_2}}{C_{D_1}}}$$

(1) "Water Tunnel Tests of the MK 13-1, MK 13-2, and MK 13-2A Torpedoes," by R. T. Knapp. Report Section No. 6.1-sr207-936, November 9, 1943

in which

T = propeller thrust in lbs

D = drag in lbs

C_D = drag coefficient

V = velocity in ft per sec

By this means the relative speeds of the torpedo with different noses have been predicted, as shown in the last two columns of Table II. Taking the speed of the MK 13-1 with the standard nose as 100%, the predicted speed for the 0.92 caliber ogive with eight spades is 79%, that of the standard nose with stabilizing ring 91%, and for the 2 x 0.35 caliber spherogive with stabilizing ring 87%.

These figures correspond to losses in speed of 7, 3, and 4.3 knots, respectively, as compared to the 33.5 knot speed of the MK 13-1 torpedo.

CAVITATION PARAMETER

In the analysis of cavitation phenomena the ratio, K, which is called the cavitation parameter has been found very useful. This is defined as follows:

$$K = \frac{P_L - P_B}{\rho \frac{V^2}{2}}$$

in which,

K = cavitation parameter

P_L = absolute pressure of the undisturbed liquid in lbs/sq ft

P_B = pressure in the bubble in lbs per sq ft which, in pure cavitation, corresponds to the vapor pressure of the liquid at the prevailing temperature

ρ = mass density of the fluid in slugs per cu ft or $\frac{w}{g}$

w = weight of fluid in lbs per cu ft

g = acceleration of gravity

V = velocity in ft per sec

It is seen, from the formula, that K can be defined as the ratio of the difference between the head in the undisturbed fluid and the head in the bubble to the velocity head. Hence, a low value of K can result from a low pressure in the undisturbed fluid (which is equivalent to the submergence), a high pressure within the bubble, a high velocity, or a combination of these factors.

CAVITATION TESTS

In order to determine the behavior of the three noses under different stages of cavitation, the models were mounted in the High Speed Water Tunnel and observations made at a water velocity of 50 ft per sec and various water pressures. High speed photographs were made of representative cavitation conditions covering a wide range of values for the cavitation parameter, K. These photographs appear as Figures 8 to 26 inclusive.

Spade Nose (No. 90). The addition of the spades to the 0.92 caliber ogive nose results in the occurrence of cavitation at much higher values of K than would be the case without them. Figure 9 shows well developed cavitation around the spades at a K of 0.6, which corresponds to a speed of 40 knots and a submergence of 10 feet, whereas other tests indicate that this ogive alone will require a K of 0.5 for *incipient* cavitation. Figure 10 shows the extension of the cavitation streamers about two calibers in length from the tip of the nose and practically continuous around the full circumference of the projectile. This condition corresponds to a K of 0.39. As the value of K decreases the cavitation bubble increases in length and diameter until the entire projectile is enveloped. Figures 11 and 12 show what would correspond to the entrance bubble at different stages of its dissipation. From these figures, which are for values of K from 0.23 to 0.20, it is seen that the bubble has attained a diameter of about two calibers, practically isolating the projectile from the water.

Hemispherical Nose and Ring (No. 91). The addition of the stabilizing ring to the hemispherical nose causes cavitation to be somewhat more advanced for the same values of K than for the same nose without the ring. It was also observed that the bubble extended nearer the tip of the nose, whereas with the henisphere alone the bubble is almost entirely aft of the point of tangency. The ripples observed in Figures 14 to 18 are caused by the ring, as the bubble on the plain nose is quite smooth and compact in appearance.

This is clearly seen in Figure 25, which shows the cavitation bubble for the nose with and without the ring at practically equal values of K. Some cavitation effect is observable on the ring for the lower values of K but, in general, the small diameter of the ring means that it is in a zone of high pressure, i.e., where the water is still being accelerated *away* from the torpedo, thus accounting for the absence of cavitation under these conditions.

Spherogive Nose with Ring (No. 92). Cavitation is perceptible on the ring in Figure 21 at a value of K = 0.67 and has increased materially for K = 0.47 as shown in Figure 22. In Figure 23 a pronounced bubble is developing at the junction of the ogive with the cylinder at a value of K = 0.33. This is practically the same in extent as has been observed with this same spherogive without the ring for a K of 0.24, as shown in Figure 26. In other words, the ring has not only induced cavitation in the ring itself, but has also materially advanced the stage of cavitation on the nose proper. In Figure 24 it is seen that a further lowering of the pressure, corresponding to lower values of K, causes the two cavitation bubbles to increase until they combine and, at a K of 0.22, completely envelope the projectile.

FIGURE 8
K = 1.02

FIGURE 9
K = 0.60

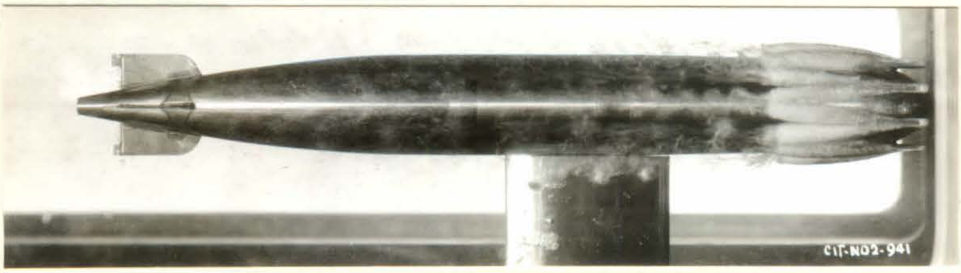


FIGURE 10
K = 0.39

FIGURE 11
K = 0.23

FIGURE 12
K = 0.20

MODEL WITH NO. 90 NOSE
(0.92 CALIBER OGIVE WITH 8 SPADES)
CAVITATION PARAMETER, K = 1.02 TO 0.20

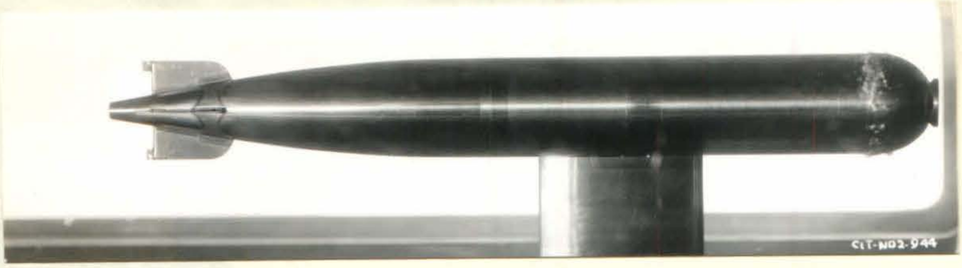


FIGURE 13
K = 0.65

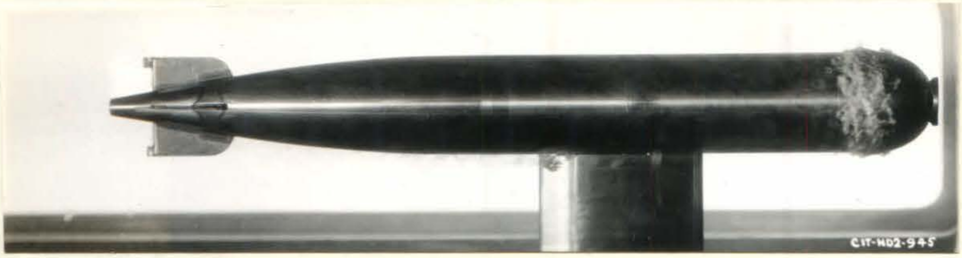


FIGURE 14
K = 0.55

FIGURE 15
K = 0.44

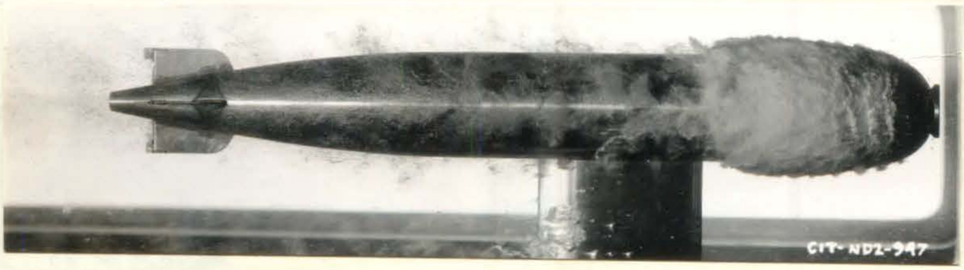


FIGURE 16
K = 0.33

FIGURE 17
K = 0.24

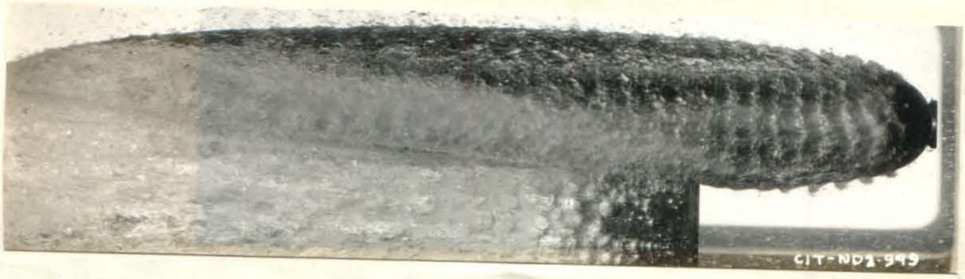


FIGURE 18
K = 0.22

MODEL WITH NO. 91 NOSE
(HEMISPHERE WITH STABILIZING RING)

FIGURE 19
K = 1.18

FIGURE 20
K = 0.87

FIGURE 21
K = 0.67

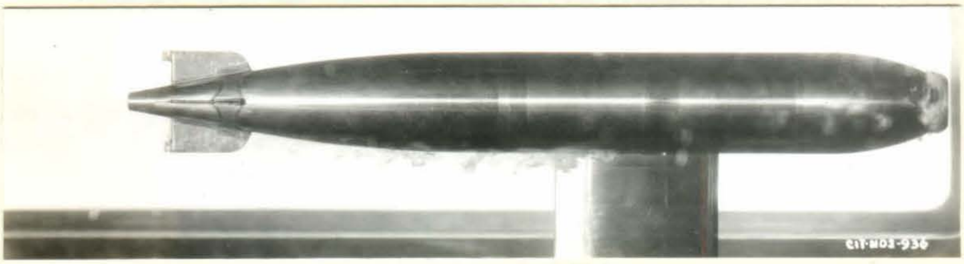
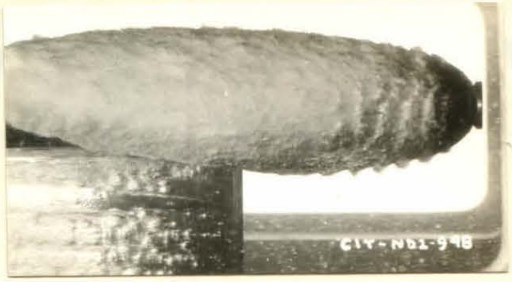


FIGURE 22
K = 0.47

FIGURE 23
K = 0.33

FIGURE 24
K = 0.22

MODEL WITH NO. 92 NOSE
(2 x 0.35 CALIBER SPHEROGIVE WITH STABILIZING RING)
CAVITATION PARAMETER, K = 1.18 TO 0.22

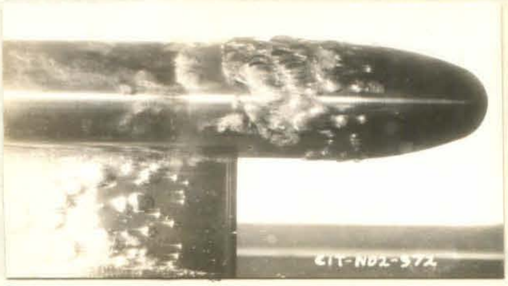


(SAME AS FIGURE 17)

K = 0.25 K = 0.24

FIGURE 25

HEMISPHERICAL NOSE WITH AND WITHOUT RING



(SAME AS FIGURE 23)

K = 0.24 K = 0.33

FIGURE 26

2 x 0.35 CALIBER SPHEROGIVE NOSE WITH AND WITHOUT RING

FLOW LINE DRAWINGS

Figures 27 to 32 are flow line drawings made from careful observations of the model in the Polarized Light Flume. This flume provides the means for determining the flow around the model at low velocities.

Figures 27 and 28 show the entire model with the No. 90 and No. 91 noses. It is seen that practically all flow disturbance occurs at the nose which is better shown in the enlarged views, Figures 29 to 32.

Figures 29 and 30 show the ogive nose fitted with spades. There appears to be no disturbance on the nose proper but a considerable amount is caused by the spades, which agrees with the photographs showing the cavitation effect. The hemispherical nose fitted with the stabilizing ring is shown in Figure 31. The small amount of disturbance in flow on the top at a point back from the junction of the hemisphere and cylinder would be expected with this type of nose without the ring. The important disturbance is caused by the ring, as clearly indicated in the drawing. It is also seen that the point of contact of the ring with the nose is also the seat of additional disturbance.

Figure 32 shows the spherogive nose with stabilizing ring. The disturbance set up by the ring on this nose is practically the same as with the hemispherical nose. All disturbance indicated in these two drawings must be attributed to the ring, as the spherogive nose would be free from this effect at the low velocity attained in the flume.

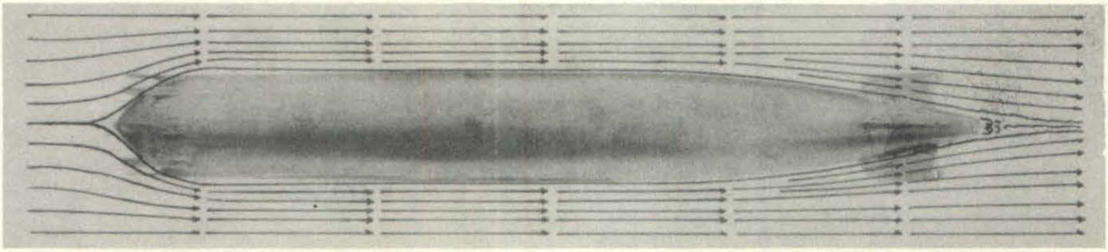


FIGURE 27
MODEL WITH NOSE NO. 90, 0° LIFT

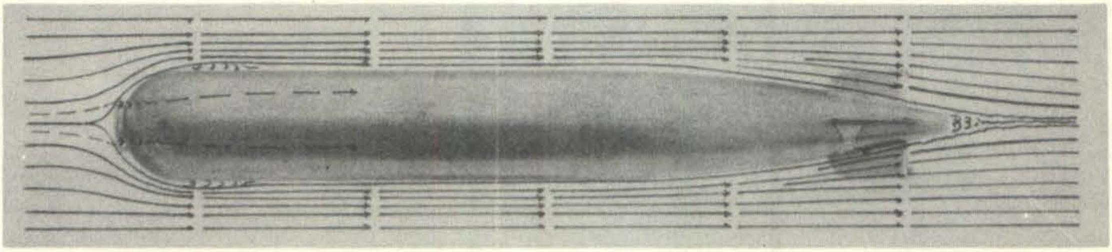


FIGURE 28
MODEL WITH NOSE NO. 91, 0° LIFT

FLOW LINE DRAWINGS OF MODELS

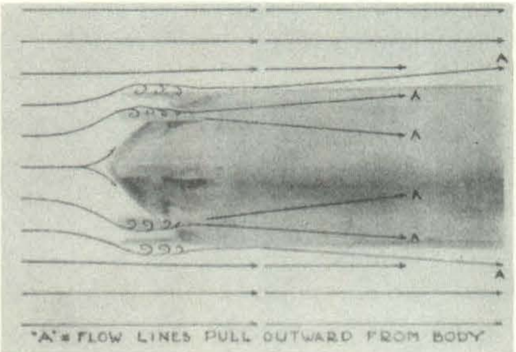


FIGURE 29
NOSE NO. 90, 0° LIFT

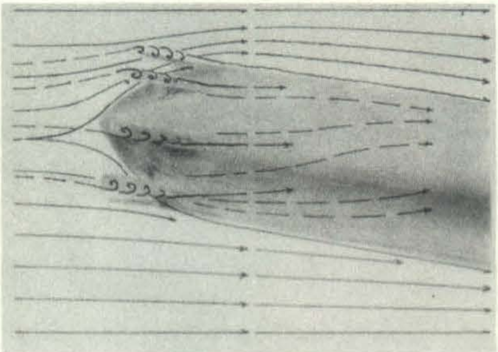


FIGURE 30
NOSE NO. 90, 10° LIFT

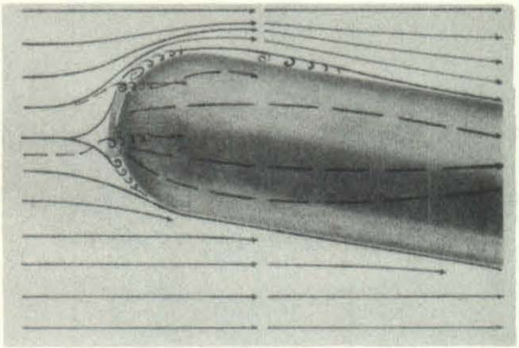


FIGURE 31
NOSE NO. 91, 10° LIFT

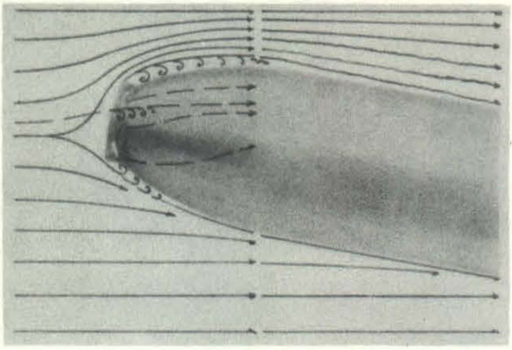


FIGURE 32
NOSE NO. 92, 10° LIFT

FLOW LINE DRAWINGS
OF NOSES

CONCLUSIONS

. In the fifth column of Table II it is seen that the drag for the torpedo with the standard MK 13-1 nose is increased from 20% to 61% by the use of a nose with spades or stabilizing rings. It is, therefore, evident that an equal increase in power would be required to drive the torpedo at its present speed if these remained on the torpedo in the steady run appendages.

It appears that, at 33.5 knots, the spade nose equipped torpedo would require a minimum submergence of about 20 feet, and the ring on the spherogive, 15 feet, if cavitation and its consequent further increase in drag were to be avoided.

Since the cavitation parameter, K, is also a measure of the persistence of the entrance bubble, it is seen that the bubble will persist until a lower velocity is reached with all these devices.

The bubble formed by the spade nose appears to be larger in diameter than that formed either by noses with stabilizing rings or the original bare standard nose. Therefore, unless this nose effectively reduces the lateral forces at entrance, larger yaws would be expected during the bubble phase because of the greater latitude of movement of the torpedo within the larger bubble.

An attempt was made to measure the drag at different degrees of cavitation. This was found to be impracticable owing to the severe vibration and oscillation of the model. As similar tests had been made previously on the same nose without any trouble due to vibration, it must be concluded that this is indicative of the characteristic behavior of this nose shape. Similar vibration and oscillation would be expected with the prototype.